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U. S. Department of the Interior
Geological Survey

Probable Future Stages of Salton Sea, by G. F. Holbrook, July, 1927

IID-53 - MEMO AND REPLY FORM

MEMO TO Mr. Hartzog

FROM Mr. Boles

Date April 26, 1949 19

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cc Mr. Hewes
cc Mr. Dowd
cc Mr. Weiss

SUBJECT

See Attached Sheets ☐

Transmitted herewith is a copy of the 1927 report by G. F. Holbrook, of the U. S. Geological Survey, on probable future stages of Salton Sea. The original of this report is filed in the General Files at Imperial.

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DATE OF REPLY 19 BY A. J. Boles

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Pasadena, California
July 18, 1927

Mr. N. C. Grover
Chief Hydraulic Engineer
U.S. Geological Survey
Washington, D. C.

Dear Sir:

To comply with instructions contained in your letters of March 2, 1927 to Mr. E. C. LaRue and July 12, 1927 to me, I am submitting herewith a report on the subject of the probable future stages of Salton Sea.

Purpose and Scope of Report:

In response to a petition filed by the water users of Imperial Valley, on March 10, 1924, Public Water Reserve No. 90 was created. The purpose of this reserve was to prevent settlement of the vacant government lands closely bordering on the shores of Salton Sea. The settlement and attempt to farm these lands had been a source of trouble to the Imperial Valley Irrigation District at those times when the fluctuations of the lake level interfered with the operations of the farmers. The purpose of this report is to determine, by a study of conditions in Imperial Valley as they are today and are likely to be in the future, the probable future stages of Salton Sea. Upon such stages will depend the advisability of enlarging, diminishing or retaining as originally made, the boundaries of the Public Water Reserve No. 90.

The solution of this problem involves an estimate of the acreage expected ultimately to be irrigated in the Imperial Valley with water from the Colorado River. It also involves the question of duty of water, drainage of lands, evaporation from the lake surface, etc. Although the opinions of engineers differ somewhat on these points, the values used in the computations upon which the conclusions of this report are based are acceptable to E. C. LaRue, to whom this problem was originally assigned.

Brief History of Salton Sea:

There are historical records of the existance of a body of water in the Salton Sink at intervals of a few years for a long period before the beginning of irrigation in the Imperial Valley. These intermittent bodies of water could only come from two sources: natural run-off from the mountains to the west and northwest, or the overflow from the flood waters of the Colorado River. Whatever the source, in the absence of a continuous inflow, the lakes thus formed soon evaporated.

It was not until the summer of 1905 that the Salton Sea as we know it today came into being. In that year the Colorado River left its old channel leading to the Gulf of California and for nearly two years, or until

February, 1907 flowed into the Salton basin. After a strenuous fight and the expenditure of an enormous sum of money, the river was finally turned back toward the Gulf.

The sea thus created covered an area of about 330,000 acres and was about 79 feet deep over the lowest point of the basin. In other words, the water rose to elevation -- 195.

For a long period of years after the break in the Colorado was closed the annual evaporation from the surface of the lake greatly exceeded the inflow from all sources and the dimensions of this remarkable body of water gradually diminished, until at the beginning of the year 1920 we find the water surface at about elevation -- 249. From January, 1920, until late in 1926 this level has been maintained with small variation. See Exhibit 1 for hydrograph of lake levels.

<u>Gages and Gage Height Records:</u>

Gages have been maintained in Salton Sea at one place or another since the water first began to accumulate there in November, 1904. In all some 8 or 10 gages have been read. Some of these recorded depths above the bottom of the sea. Others were inverted and read elevations below sea level. Records have been collected by the U. S. Geological Survey, the Southern Pacific Railroad Co. and the Imperial Irrigation District.

Discrepancies have been observed in the elevation of the datum planes of these various gages. For this reason, the gage heights have not been published since 1918.

In 1923, Mr. F. C. Ebert, Hydraulic Engineer, U.S.G.S., made a field investigation and reported the result of his study of this problem to Mr. McGlashan, District Engineer at San Francisco. On the basis of Mr. Ebert's report the published and unpublished gage height records have been corrected and are presented herewith in the form of a hydrograph (Exhibit I).

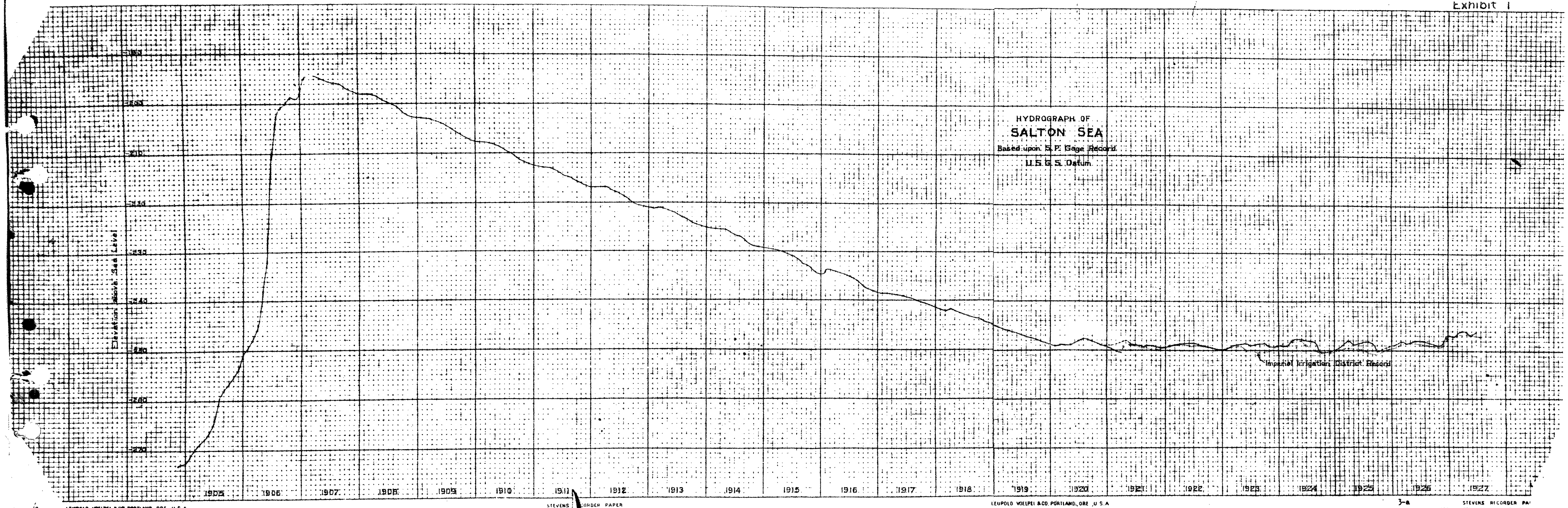
This hydrograph is mostly a record of gage heights obtained by the Southern Pacific railroad from gages on the east shore of the sea near the station of Durmid. From May, 1921, to date the Imperial Irrigation District has kept a record of the stage of the water in the sea at widely divergent points along the shore. Their record up to the end of 1923, taken at the south end of the sea, is based upon a U.S.R.S. bench mark at Niland. Through 1924 and part of 1925 they read a gage opposite Salton which was based upon a U.S.G.S. bench mark at Montmere station of the Southern Pacific. From July, 1925 to date their — 1925 Fig Tree John record was taken at Fig Tree John's Spring, on the northwest shore of the sea, and this is also based upon a U.S.G.S. bench mark.

The irrigation district record is shown on the hydrograph as a dotted line. Except during the summers of 1923, -24 and 25, it parallels the S. P. record rather uniformly but indicates a stage about one-half foot lower. During those periods excepted above, it drops below the S. P. record by as much as 2 feet.

On May 13, 1921, the present Southern Pacific gage was established with zero at sea level. The corrected reading from the preceding gage indicates a stage, on March 31, 2.3 feet lower than that of the new gage on May 13. 2.3 feet at this stage of the sea is equivalent to nearly 400,000 acre-feet of water. The winter and spring of 1921 was a period of deficient rainfall, so there could have been no storm water entering the sea. The inflow from New and Alamo rivers from March 31 to May 13 was about 75,000 acre-feet. Assuming that the old gage record has been correctly adjusted on the basis of its original datum, a possible explanation of the failure of the records to match up at this point is that the old gage was becoming loose and gradually rising under the effect of wave action for some time before it finally failed. If this theory is correct, the dashed line from Dec. 1, 1920 to May 13, 1921, probably represents the approximate water stage.

A picture of the present Southern Pacific gage is shown on page five a.

Exhibit 1


HYDROGRAPH OF
SALTON SEA
Based upon S.P. Gage Record
U.S.G.S. Datum
Elevation above Sea Level
Imperial Irrigation District Record
1905
1906
1907
1908
1909
1910
1911
1912
1913
1914
1915
1916
1917
1918
1919
1920
1921
1922
1923
1924
1925
1926
1927

Southern Pacific gage in Salton Sea
near Durmid, California. April, 1927.

Topography of Drainage Basin:

If the Colorado River be left out of consideration, the basin whose drainage is tributory to Salton Sea is not large. It consists of about 7,500 square miles and lies mostly north of the international boundary line. There are perhaps 1000 square miles in Lower California whose drainage flows toward the Salton Sea. See map of basin, Exhibit II, in pocket.

The central portion of the south half of this basin constitutes the area known as the Imperial Valley. It is a broad, flat alluvial plain, a deposit of Colorado River silt of vast depth. It is the north half of the ancient Colorado River delta cone. The northerly slope of these lands south of the international boundary line is slight, about $1\frac{1}{2}$ feet to the mile. North of Heber, which is some four or five miles within the United States, the slope increases to 6 or 7 feet to the mile. On either side of the improved portion of Imperial Valley are found mesa lands of a more sandy texture, which constitute about 75% of the additional lands to be irrigated by the proposed All-American Canal. The east mesa terminates on its easterly edge in a ridge of wind blown sand hills which are the chief obstacle to the construction of the All-American Canal. On the west side of the valley the mesa lands merge into foothills which culminate in the dividing ridge between Salton Basin and Pacific Coast drainage at an elevation of 5000 feet above sea level.

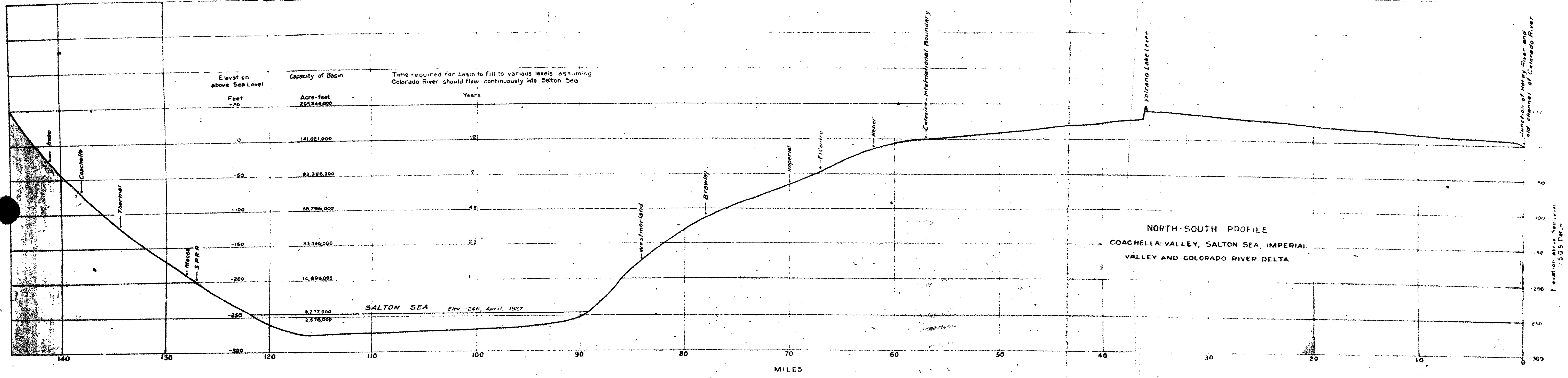
The portion of the basin lying north of Salton Sea is a region of great relief. The Whitewater River is the main stem of the drainage system here. This stream has its head on Mount San Gorgonio, over 11,000 feet above sea level, and discharges its floods of snow water into Salton Sea at 250 feet below sea level. The total length of this intermittent stream is about 70 miles, and it drops from its source to sea level in a distance of about 50 miles.

About twenty miles south of Mt. San Gorgonio is another high peak, Mt. San Jacinto, slightly less than 11,000 feet high. Between these two mountains lies San Gorgonio Pass, sometimes called Beaumont Pass, through which most of the railroad and highway traffic between the valley and the coast region passes. The town of Beaumont is at the summit of this pass at elevation 2600 feet.

On the floor of the valley near the north end of Salton Sea lies the region known as Coachella Valley. Some of this land is irrigated today from wells, and there are nearly 100,000 acres here, lying mostly below sea level, most of which could be irrigated by gravity under the All-American Canal project.

Exhibit III is a profile along the center of Imperial and Coachella Valleys and the Salton Sea. It shows in a graphic manner the time required to flood the various towns in the valleys, should the Colorado River flow unchecked into the Salton Sea.

Exhibit III


NORTH-SOUTH PROFILE
COACHELLA VALLEY, SALTON SEA, IMPERIAL
VALLEY AND COLORADO RIVER DELTA
Elevation above Sea Level
Feet
Capacity of Basin
Acre-feet
Time required for basin to fill to various levels assuming
Colorado River should flow continuously into Salton Sea
Years
+50
205,546,000
0
141,021,000
12
-50
93,396,000
7
-100
58,796,000
4½
-150
33,346,000
2½
-200
14,896,000
1
-250
3,277,000
2,376,000
-300
SALTON SEA
Elev -246, April, 1927
Indio
Coachella
Thermal
Mecca
S.P.R.R.
Westmorland
Brawley
Imperial
El Centro
Heber
Calexico-International Boundary
Volcano Lake Levee
Junction of Hardy River and old channel of Colorado River
Elevation above Sea level U.S.G.S. Datum
MILES
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0

Precipitation and Run-Off

Salton Basin is pre-eminently a desert region. Precipitation records, extending back 50 years at two stations within the basin, indicate a mean annual rainfall of 2.24 inches in one case (at Sterling, formerly Mammoth Tank) and of 2.81 inches in the other (at Indio). Individual years in these records range from a trace to over seven inches. Most of the rainfall comes in the winter months, from December to March inclusive, although occasionally heavy downpours of cloudburst intensity may occur in the summer months.

The principal inflow to Salton Sea from precipitation within the basin comes from the high westerly rim of the basin. Winter storms passing inland from the Pacific Coast produce a heavy rain and snowfall in these mountains, whose highest peaks are frequently covered with snow until late in the Spring.

In studying precipitation records within the Salton Basin, four or five stations have been selected as being representative of the two regions above described. On the floor of the basin, Indio is located near the north end of Salton Sea, and Sterling or Brawley records have been used to indicate the precipitation at the southerly end. The station at Cuyamaca, on the rim of the basin in San Diego County at elevation 4677 feet, gives a fair measure of the rain fall in that region. Beaumont, at elevation 2558, is located on the divide near the Northwesterly end of the basin.

Due to the absence of records of discharge of the streams draining the westerly rim of Salton Basin, it is not possible to obtain a correlation between precipitation and run-off. The best that can be done is to study the effect on the level of Salton Sea of the outstanding storms of the period of record.

Considering the mountain stations, the records indicate that January, 1916, was the "wettest month" in the period of forty years during which these stations were kept. In that month 16.16 inches are recorded at Beaumont and 36.50 inches for Cuyamaca. In each case the figures are within two or three inches of the mean annual precipitation for the station. Indio received 3.53 inches, which is more than the mean annual. The rainfall in the south end of the valley was not so great. The storms of this period were responsible for the great floods in Southern California which are described in Water Supply Paper 426.

The effect of this unusually stormy month on Salton Sea is indicated in the hydrograph. For the first time since the sea began to recede in February, 1907, the water level rose again. The gage record indicates a rise of .6 of a foot and this stage was maintained until the middle of the following March. Without this natural inflow, the excess of evaporation over the amount of waste into the sea from Imperial Valley would have had the effect of lowering the sea about .9 of a foot during this period. Hence a total of about 1.5 feet over the area of the sea may be attributed to the storms of January, 1916. At the stage of the sea at that time (--237), this is equivalent to an inflow of about 330,000 acre-feet.

The precipitation in the months of February and March, 1916, was very light. If the storms of January had been followed by a continuation of heavy rainfall in those months, as might easily happen in a wet cycle in Southern California, the total inflow of storm water to Salton Sea might have reached 500,000 acre-feet. In estimating possible future stages of the sea, that figure will be used as the maximum contribution likely to be received from storm run-off.

Storm Runoff ?

Character and Value of Lands Bordering Salton Sea:

The lands bordering closely upon the present shore line of Salton Sea vary somewhat in texture at opposite ends of the sea. Those at the north end, in Coachella Valley, while probably coming under the classification of silt loam, are inclined to be somewhat more sandy than at the southerly end of the sea. The low lying bottom lands in the center of Coachella Valley are heavily impregnated with alkaline salts, and cannot be used for growing crops until drainage has been provided and the salt content lowered by leaching. For lands lying but slightly above and on the immediate shore of the sea, this process of reclamation might prove difficult because of the nearness to the surface of the permanent ground water level. Lands lying near the north end of Salton Sea have no agricultural value now, and but small prospect of ever being reclaimed.

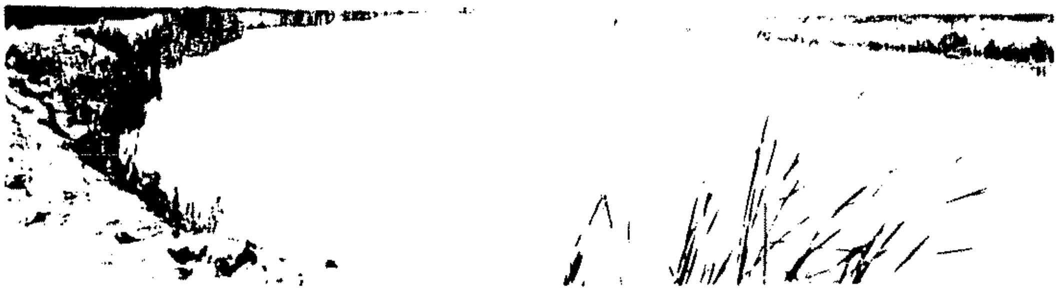
For a distance of about 20 miles, the Southern Pacific Railroad parallels the northeast shore of the sea at an elevation slightly more than 50 feet above the present water level. The strip between sea and railroad will average a little over one-half mile in width. The lower portion of the strip is salty but the higher lands appear to be well drained and rather sandy in texture. The southerly end of the strip is badly cut up with small washes. The Imperial Valley - Coachella Valley high line canal survey passes above this land, but at a distance varying from 2 to 7 miles away. Because of the high cost of bringing water to this relatively small acreage, it is not likely that this land will ever be irrigated.

The west shore of Salton Sea is somewhat flatter in slope than the east, and has several bodies of arable lands, situated mostly above the -- 200 foot contour. The -- 220 foot contour is everywhere well below these lands. From the water level up some 15 or 20 feet the lands are quite salty and unsuitable for reclamation. On page 14, is shown a picture of this shore of the sea opposite Fig Tree John's Spring.

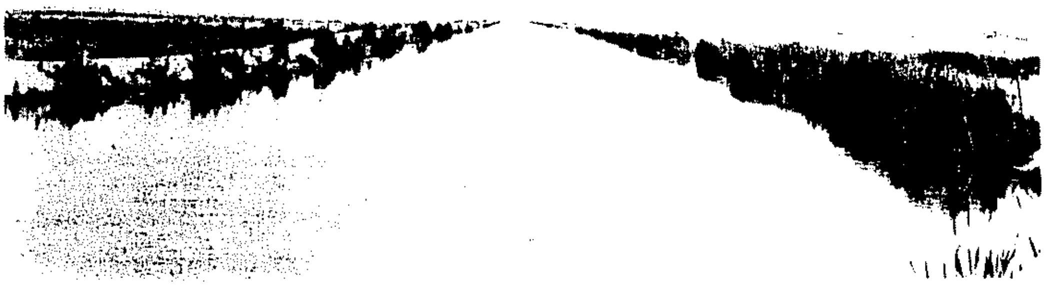
The boundary of the Imperial Irrigation District roughly follows the southeasterly shore of the Salton Sea for about twenty miles. The land here is generally a heavy silt or clay loam and has a slope toward the sea of about 10 feet per mile. Close to the water's edge the slope is less, probably 5 or 7 feet to the mile. Here also the lands bordering the sea are quite salty, so much so that large patches, acres in extent, are absolutely bare. About the only thing that does grow here is a kind of salt-resistant brush.

Alamo and New Rivers enter the Salton Sea a few miles apart in this region. These streams, like the Colorado River itself, are heavily silt-laden and are each doing, on a miniature scale, what the parent stream has done for ages - building a delta at its mouth. These rivers flow in well-defined cut channels until they reach about elevation -- 240, a couple miles from the sea. Here the delta building begins, and the streams have a tendency to spread out and swing from side to side, dropping the silt load upon the old salt-impregnated sea bottom. Thus, in recent years, at the mouths of these rivers a limited area of good soil has been built up. As the streams have recently been confined to dredged channels leading to the sea between dikes, it is expected that the built-up areas may soon become dry enough for farming operations. The areas close to the mouths of the rivers constitute the only lands near the Salton Sea that may be profitably farmed in the near future. The pictures on page 13, show the dredged channel of New River near the common corner of Sections 9, 10, 15 and 16, T. 12 S., R. 12 E. That on page 14, is the Alamo River dredged channel in Sec. 17, T. 11 S., R. 13 E.

Every alternate section of land (the odd-numbered sections) in the bottom of the Salton Sea and around its border are owned by the Southern Pacific Company.



Down-stream view of New River at bend in dredged channel near common corner of sections 9, 10, 15 and 16, T.12 S. R.12 E. May, 1927.



Up-stream view of New River taken at same place as upper picture on this page. May, 1927.

Dredged channel of Alamo River near its mouth. May, 1927.

West shore of Salton Sea opposite Fig Tree John's Spring. May, 1927.

The submerged land is of course worthless at this time. It is assessed at $50 per square mile, just to hold it on the County Assessor's books. Privately owned lands bordering on Salton Sea are absolutely worthless, from an agricultural point of view. On a 50 percent of valuation basis, they are assessed at from $1 to $3 per acre. A little farther back from the shore, but still below contour -- 240, the assessments run from $5 to $10 per acre. Near the mouth of Alamo River there is a small acreage at this elevation that is assessed at $25 per acre. Between contours -- 240 and -- 230, values run somewhat higher, assessments ranging generally from $10 to $30 per acre within the irrigation district, with a few tracts placed at figures above and below those limits. There is very little land in this belt that is being farmed today.

Between contours -- 230 and -- 220, we begin to find considerable farm land which is assessed at $40 to $60 per acre. The best land in this belt lies in the 8-mile stretch of country between the New and Alamo Rivers. All assessments quoted here are said by the County Assessor to be upon a 50% of valuation basis.

Southern Pacific Company Lands:

On June 22, 1916, the Southern Pacific Land Company entered into an agreement with the Imperial Irrigation District, granting to the district a flowage right-of-way over certain

Southern Pacific lands in and around the then existing Salton Sea, for the purpose of storing and evaporating the waste water from the Imperial Valley irrigation system. The contract, with description of lands excluded, is presented below.

THIS INDENTURE made this 22nd day of June, 1916, by and between the SOUTHERN PACIFIC LAND COMPANY, a corporation organized under the laws of the State of California, party of the first part, and IMPERIAL IRRIGATION DISTRICT, an irrigation district organized under the laws of the State of California, party of the second part,

WITNESSETH;

That, pursuant to the terms of that certain agreement between the Southern Pacific Company, a corporation, and Imperial Irrigation District, dated December 28th, 1915, the party of the first part does hereby grant unto the party of the second part the right and easement to flow any excess water from the irrigation system used for the irrigation of the region known as the "Imperial Valley" over and upon the following described lands of the party of the first part:

(Legal description of lands omitted)

Provided, that this right and easement shall not be construed to permit the said party of the second part to overflow any of the lands of the party of the first part, not now submerged by the waters of the so-called Salton Sea and lying above a contour line 238 feet below the sea level; and provided, further, that as the level of said Salton Sea may be lowered by reason of the excess of evaporation over the normal inflow of waters, and the water thereby caused to recede from any additional lands of the party of the first part, all such lands lying three feet above the highest level of water in said sea during any calendar year shall thereafter be free from the said easement of overflow and thereafter it shall be the duty of the party of the second part to so regulate the inflow of waste waters from its irrigation canals and ditches into the Salton Sea that there shall be no resubmergence, except as above provided, of such lands of the party of the first part from which, by the due natural process of excess of evaporation over inflow of water, the waters of said Salton Sea shall have receded; and provided, further, that nothing herein contained shall be taken to prejudice or affect any right which the party of the first part might otherwise have to use waste water from said irrigation system of the party of the second part..

IN WITNESS WHEREOF the part of the first part has, by its officers therunto duly authorized, hereunto signed its corporate name and affixed its corporate seal all on the day and year first above written.

SOUTHERN PACIFIC LAND COMPANY.

(Signed) By - W. Sproule - President.

S E A L

(Signed) By - G. S. King - Secretary.

It will be noted that the contract provides that the irrigation district shall not be permitted to overflow any of the Company lands not then submerged, and lying above a contour line 238 feet below sea level. As a matter of fact, the corrected gage heights indicate that the water stood at about elevation --235 at the time the easement was given, or three feet higher than the contour mentioned. However, the first part of the clause indicates that the intent was only to limit the elevation to that at which the sea then stood, irrespective of datum planes.

The contract further provided that, as the water surface receded, the highest stage in any calendar year became a basis from which to estimate the stage to which the water should be permitted to rise at any time subsequent to that year. That is, all lands lying 3 feet or more above the lowest maximum stage of any calendar year were thereafter released from this flowage right-of-way, and the limiting stage for the water of the sea thus became automatically reduced to an elevation lower than the original -- 235 feet.

The following quotation is from a letter to Mr. LaRue from B. A. McAllaster, Land Commissioner for the Southern Pacific Company, dated April 29, 1927.

"The record maintained by the District showing the elevation of water in the Salton Sea from month to month during the period which has elapsed since 1916 shows that during the calendar year 1925 the highest elevation attained by the waters of Salton Sea was 249.6 feet below sea level, therefore the highest level now permitted under the agreement would be 246.6 feet below sea level.

All those lands described in said agreement lying above the contour -- 246.6 feet have become free of any obligation resting upon said agreement.

The level on April 1, 1927 was -- 246.7 feet or within one-tenth of a foot from the limit.

We would seriously object to any plans for increasing the level of Salton Sea above the contour 246.6 feet below sea level above mentioned."

Reference to the hydrograph of the sea (Exhibit 1) reveals that in 1925 the Southern Pacific gage recorded a maximum elevation of -- 248.0, instead of -- 249.6. The same gage in 1922 gave a maximum stage of -- 248.5, which would place the upper limit of the easement at -- 245.5, instead of -- 246.6. This gage on April 1, 1927, read -- 246.0, allowing .5 foot leeway instead of .1 as in the above quotation. The contract appears to be weak in not specifying the gage and datum by which the stage of the sea shall be determined.

It is readily seen that this contract will prove an impediment to the Imperial Irrigation District if future growth of the acreage irrigated should make it necessary to waste more water into Salton Sea than at present. During the last two years the district and the railroad Company have given this problem some consideration. It has been tentatively proposed that the district buy the lands affected from the railroad Company. Another suggestion was that the Company accept other government lands of equal value in lieu of the Salton Sea lands affected. In either case, the irrigation district would have to secure a flowage right-of-way from the Interior Department, the only difference being in the extent of the lands affected by such right-of-way. The chief obstacle in the way of settling this Southern Pacific land problem seems to be a difference of opinion as to the value of the lands.

Irrigation District Problems affecting Salton Sea:

The Imperial Irrigation District, by reason of its location at a considerable distance from the source of water supply, and also because of the silty character of its water, has problems of operation and maintenance that are not usually encountered in irrigation projects in the United States.

The length of the Alamo Canal, from the point of diversion to Sharps Heading at the International Boundary Line is about 50 miles. From this point to the lower end of the East High Line or the West Side Main Canal is over 50 miles. Some of the water deliveries under the present system are made at distances well over 100 miles from the point of diversion, and a time interval of as much as two and one-half days is required for this water to pass from the Colorado River to the land. With the extension of the system made possible by the construction of the All-American Canal, the extreme limit of the canal into Coachella Valley will be about 180 miles from the Colorado River at Laguna Dam.

This great length of the system, and the fact that it is usually considered necessary to be able to deliver water to the farmer on less than twenty-four hours notice, requires a large flow of water to be maintained in the canals at all times. Thus it becomes necessary at times to waste considerable water from the system. The New and Alamo Rivers are admirably situated in the valley to receive and carry off this waste water. However, it has been necessary to construct some 600 miles of waste ditches to carry the water to these natural channels.

The greatest problem in the operation of the Imperial canal system undoubtedly arises from the high silt content of the water. Trouble from this source begins at the very head of the system and is always present, even down to the point where the waste water enters Salton Sea.

The diversion works at Hanlon Heading were constructed without any provision for de-silting the water. Consequently, the Canals, flowing at moderate velocities, have a constant tendency to drop the silt to the bottom. Thus the capacity of the canals becomes less and the water surface tends to rise, at times even to the danger point of over-flowing and breaking the banks. The bed load of sand and heavy silt in the main canals varies with the flow, and can be somewhat controlled by sluicing with a large head of water. This is true throughout the system, and it is the sluicing operations in the canals that is chiefly responsible for the large proportion of waste water from the system.

In all there are some 2,600 miles of canals, waste ditches and drains in Imperial Valley. If placed end to end, they would reach from Los Angeles to New York and on out to the east end of Long Island. Sluicing does not completely solve the silt problem. A vast equipment of dredges of various kinds is maintained to clean out the canals. During the years 1923 and 1924, over 2400 miles of Canals were dredged in the valley. Leaving out the drains, which flow clear water, this means that practically every mile of the entire system was maintained by dredging during that two year period.

Included in the system are some 134 miles of dead-end laterals. These can only be cleaned by shoveling, which is the most expensive kind of maintenance. This expense can only be reduced by providing outlets to these canals and resorting to sluicing.

At several places in its passage to Salton Sea this accumulation of waste water encounters a drop which makes possible the development of power. The irrigation district is planning the installation of power plants at these points.

In a preliminary report, the Chief Engineer of the district estimates that 3100 horsepower could be developed at three plants to be located at Rositas dam, Alamo dam and No. 8 heading. The officials of the district state that it is their intention to use only the natural and necessary waste water for this purpose, and that this development of power will not result in an increase in the amount of water diverted from the Colorado River.

3100 HP

In connection with the subject of waste water, I wish to quote from a letter to Mr. LaRue from Mr. M. J. Dowd, Chief Engineer and General Superintendent of the Imperial Irrigation District, dated May 3, 1927.

"I know a good many have the impression that we are wasting excess water in order to maintain the sea at a higher level but this is not true and I emphatically wish to state that at no time during my connection with District operations have we ever diverted a second foot from the Colorado River for the purpose of either maintaining or raising the elevation of Salton Sea. The opposite is true as I have stated, and we have found it necessary to curtail our waste to some extent in order that we not raise the sea.

As previously mentioned, in our proposed plans for power development we do not anticipate diverting additional water for power purposes but will utilize only the necessary waste and canal flow as now exist. As further evidence of this, we are planning on a stand-by plant which will be capable of carrying the power load if no water is available for the hydro plants.

Surely as a result of your study of the Colorado River and its silt characteristics you can appreciate our problem of controlling the flow in our canals and properly maintaining them to give satisfactory service. The action of bed sand in our major canals is most troublesome and fluctuations of as much as seven and eight hundred second feet have been noted from this cause in the Alamo Canal, making it necessary to have available considerable regulatory waste. Also over a large part of our system it would not be economically feasible to maintain an adequate flow without sluicing and when it is borne in mind that we have come 2600 miles of canals it must be appreciated that considerable water is necessary for this purpose.

One other factor, is the length of our canals, It requiring as much as two and one-half days for water to reach certain points from Hanlon Heading so that combined with the sluicing water there must be an amount available in order to give quick delivery when needed.

I mention these points in view of the existing belief in certain parts, as I have already mentioned, that the District is unnecessarily wasting water and in order to impress upon you that any curtailment would mean inefficient control and improper maintenance of our canals."

Use of Water in Imperial Valley:

The Imperial Irrigation District and its predecessor, the California Development Company, have kept records of the water diverted and the use to which it was put for many years. A summary of the water records, together with weather and crop data, are published in the 1924 annual report of the Chief Engineer of the district. These data go back to the year 1912 and have been brought down to include the records for the year 1926, so that a view of the water situation in the valley over a 15 year period is presented. The record is presented in the form of a hydrograph (See Exhibit IV in pocket). This shows the water delivered, water wasted and water lost (Canal losses by evaporation, seepage, etc.) and the total of these three equals the total annual diversion from the river.

On January 1, 1923, a change was inaugurated in the method of keeping these records. Previous to that date the water delivered, wasted and lost was based upon deliveries to the Mutual Water Companies at their headgates, therefore up to that time the water delivered includes the loss and wastage from the lateral systems. On November 1, 1922 the water companies went out of existence and their duties were taken over by the irrigation district. Deliveries were then made directly to the farmer and the water records from Jan. 1, 1923 to Dec. 31, 1926, present a true picture of the use of water by the system as a whole during that period.

The following table has been prepared, computed from the records as published. It therefore must be studied with the above explanation of the meaning of the records kept in mind:

Use of Water in Imperial Valley,
United States and Mexico,
in Acre-feet per Acre Irrigated.

Year	Water Diverted	Water Delivered*	Water Wasted*	Canal Losses*
1912	5.93	3.77	1.12	1.03
1913	6.04	4.05	.93	1.07
1914	5.88	4.12	.74	1.01
1915	5.71	3.87	.71	1.14
1916	5.76	3.83	.93	1.00
1917	5.53	3.86	.80	.86
1918	5.66	3.93	.80	.93
1919	4.86	3.53	.89	.43
1920	5.13	3.45	1.28	.40
1921	4.77	3.40	1.16	.20
1922	5.13	3.79	1.07	.27
Mean	5.49	3.80	.95	.76
1923	6.18	2.89	2.25	1.04
1924	5.66	3.06	1.38)	1.22
1925	5.38	3.03	1.53)Mean	.82
1926	5.66	3.31	1.56) 1.49	.79
Mean	5.72	3.07	1.68	.97

*Note - From 1912 to 1922 water delivered, wasted and lost is based upon deliveries to the Mutual Water Companies at their headgates, and the water wasted and lost applies to main canal system only. From 1923 to 1926, deliveries were made to the grower, and the water wasted and lost applies to the entire system.

The average amount of water delivered to the mutual water companies from 1912 to 1922 was 3.80 acre-feet per acre irrigated. From 1923 to 1926, the average amount delivered to the growers was 3.07 acre-feet per acre. The difference of

.73 acre-feet per acre may be attributed to canal losses and water wasted from the distribution systems of the mutual water companies.

The Canal losses, from the main canal system only, from 1912 to 1922 averaged .76 acre-foot per acre, while from 1923 to 1926 it was .97 acre-feet per acre from the entire system. The difference is .21 acre-feet per acre, which represents the losses in the distribution system. Therefore, .73 minus .21, or .52 acre-feet per acre represents the average amount of water wasted from the distribution systems of the Mutual Water Companies.

The average wasted water from the main canals for the period 1912 to 1922 was .95 acre-feet per acre, and the average wasted water from the entire system should be represented by .95 plus .52 or 1.47 acre-feet per acre for the period 1912 to 1922 inclusive.

It will be noted that the column for canal losses does not appear to be as uniform as might be expected. It is evidently obtained by subtracting the water delivered plus the water wasted from the total amount diverted. The diversion and the deliveries are measured quantities but the water wasted is an estimate and therefore probably subject to a greater percentage of error. Any error in this column would cause an equal error, but of opposite algebraic sign, in the column of canal losses. The later records, from 1919 to 1926, are known to be the more accurate. Therefore the values for water wasted previous to 1919 are probably too low, producing a correspondingly too high value for canal losses during those years. However, the relation between these two columns is such that any correction applied to one involves such a corresponding correction in the other that, when used in the above computation, the effect is compensating and the final result is not changed. This fact is shown algebraically as follows:

Let D equal average delivery from entire system.

d equal average delivery from main canals.

W equal average waste from entire system.

w equal average waste from main canals.

L equal average loss from entire system.

l equal average loss from main canals.

Then $(W-w)$ equals waste from laterals

and $(L-l)$ equals loss from laterals.

Therefore $(d-D) = (W-w) + (L-l)$

and $W = (d-D) + (w+l) - L$

$(w+l)$ represents sum of waste and loss from main canal system. If the estimate of waste in any year should be increased, the value in the canal loss column will be correspondingly reduced and the sum of the two values $(w+l)$ does not change.

Therefore $W = .73 + 1.71 - .97$

$W = 1.47$

The flow of the Colorado River in the summer of 1923 was unusually steady. During the three low water months of August, September and October the river discharged over

3,500,000 acre-feet, and the lowest month (October) yielded 734,000 acre-feet as against 240,000 acre-feet in 1922 and 184,000 acre-feet in 1924. As a result of this condition there was a plentiful supply of water all through the year 1923 for canal regulation and sluicing, and the total amount of water wasted from the canal system that year was abnormally high. Eliminating 1923, the average value of the water wasted from the entire system since the district began making deliveries directly to the grower is 1.49 acre-feet per acre, which is very slightly more than the average figure for that value as computed above through the period 1912 to 1922. It is believed that 1.5 acre-feet per acre is a good average value to use in estimating the amount of water that is likely to be wasted from the system of the Imperial Valley Canals.

The largest area ever irrigated in Imperial Valley, on both sides of the international boundary, was 603,000 acres, in the year 1920. Since that year, the irrigated area has ranged from 530,000 acres to 586,000 acres, and has averaged about 550,000 acres. This is only about one-half of the total irrigable area that may be placed under ditch when the All-American Canal is constructed.

The following table shows the acreage that may ultimately be expected to be irrigated in the Imperial Valley:

	Acres
Imperial Irrigation District (as in 1927)	515,000
East Mesa	170,000
West Mesa	120,000
Coachella Valley	98,000
Total in United States	903,000
In Mexico	253,000
Total:	1,156,000

The 603,000 acres irrigated in 1920 constituted about 79% of the then irrigable area. The average area of 550,000 acres irrigated since that year amounts to about 72% of the irrigable area. It seems reasonable to assume that, under future conditions, 80 percent of the land under ditch might be irrigated each year. 80% of 1,156,000 acres is 925,000 acres.

It is to be expected that the construction of the All-American Canal and the extension of the system will modify the operating problems of the system to some extent. However, the enlarged system and the great length of some of the new main canals will still require a large amount of water to be wasted in canal regulation.

The Yuma project, diverting at Laguna Dam, is able to eliminate about half the silt from the water entering its canal system. Their maximum canal flow is only 1200 second-feet, and the nearness of their lands permit a weekly shut-down of the canal headgates to facilitate sluicing out the de-silting basins. Should the All-American Canal be constructed, the diversion at Laguna Dam would be increased about 9-fold, or to

10,600 second-feet. There is considerable doubt whether desilting operations upon such a large scale would be as efficacious as at present. It is recognized that storage of Colorado River water will remove the silt at the reservoir, but it is believed that for many years the stream will pick up a new burden of silt from the deposits in the channel between the reservoir and the point of diversion. Possibly the silt problem in the All-American Canal system will still require the use of considerable waste water for canal sluicing. Water used for this purpose would ultimately find its way into Salton Sea.

With the All-American Canal in operation, the Imperial Irrigation District will no longer have any control over the Canal system serving the Mexican lands. Considerable waste water from these lands will undoubtedly flow down New River into Salton Sea for many years to come.

For the reasons enumerated above, it does not seem likely that there will be a very great reduction in the amount of waste water entering Salton Sea, per acre of land irrigated. Therefore, the value of 1.5 acre-feet per acre, which has been shown to be wasted under present conditions, is assumed to represent the amount of water that it will be necessary to waste into Salton Sea under conditions of future development. With an average area of 925,000 acres irrigated, this assumption indicates that about 1,387,000 acre-feet of water may be expected to be wasted into Salton Sea annually.

Evaporation:

In 1909 and 1910, the U.S. Weather Bureau studied evaporation at stations located at several points in Salton Basin, as well as at other points in the United States. The purpose of this investigation was to determine a general formula for evaporation under any and all conditions of temperature, altitude, humidity, wind velocity, etc. To obtain a practical check on one of the co-efficients used in the formula adopted, the result by the formula was compared with the computed evaporation from Salton Sea based upon change of stage and measured inflow and rainfall. This data, obtained by co-operation with the U.S. Geological Survey, for the year June 1, 1909 to June 1, 1910, indicated an evaporation from the sea during that period of 5.75 feet.

In Water Supply Paper 395, page 142, an estimate is made of the amount of evaporation that took place from the surface of Salton Sea during the seven year period 1907 to 1913 inclusive. The result of this study indicates an average annual evaporation from the sea of 5.8 feet. Assuming as correct this value for the rate of evaporation, in order to evaporate the 1,387,000 acre-feet of water which it has been estimated may ultimately be wasted into Salton Sea annually, the area of the surface exposed would have to average about 239,000 acres. This area is found at elevation -- 228. See area and capacity curves of Salton Sea, Exhibit V.

During the period 1920 to 1926 the evaporation from the

Salton Sea practically balanced the inflow from all sources, and the variation in the stage of the water was limited to a range of about 2½ feet. During the winter of 1926-1927, the sea rose about 3 feet, reaching a higher stage than it had known since 1919. The capacity curve of the sea, for a range of 3 feet at this stage indicates a gain of about 500,000 acre-feet of water. A large part of this is of course due to the usual upward trend of the graph during the winter months, when the continued steady inflow from Alamo and New Rivers exceeds the reduced evaporation. However, there was a large inflow of storm water in Dec. 1926 and again in February 1927, and the unusual stage of the sea in the spring of 1927 must be attributed chiefly to this fact.

In discussing precipitation and run-off within the Salton Basin, it was estimated that 500,000 acre-feet of storm water might flow into Salton Sea in a very wet winter. If under future conditions it should be necessary to hold the sea at an average stage of -- 228 to evaporate the waste water from Imperial Valley, it is very possible that a storm inflow of 500,000 acre-feet might occur at a time when the water level was above the average, say at --227 or -- 226. At that stage of the sea, a flood of that magnitude would raise the water about two feet, or say to elevation -- 225 or — 224.

With the surface of Salton Sea continuously at or near elevation -- 228, and the possibility always present of a higher stage, up to elevation -- 225 or -- 224, the business of farming along the shores of the sea would be very uncertain. It is believed that under these conditions, the ground water level of any lands lower than -- 220 feet would be so close to the surface that it would be impossible to prevent the rise of alkaline salts.

Conclusions:

(a) Lands bordering on Salton Sea below elevation -- 240 are worthless from an agricultural point of view. Those between elevation -- 240 and -- 230 are worth very little except in the near vicinity of New and Alamo Rivers. Lands lying between elevations -- 230 and --220 are generally valuable for farming within the boundaries of the Imperial Irrigation District. Outside of the district, lands at this elevation are not classified as arable by the Strahorn soil survey.

(b) The Contract between the Southern Pacific Company and the Imperial Irrigation District, granting a flowage right-of-way to the district, will be an impediment that will have to be removed before the irrigation district can waste any more water into Salton Sea than at present.

(c) The maximum amount of storm water that may be expected to flow into Salton Sea in a very wet year is 500,000 acre-feet.

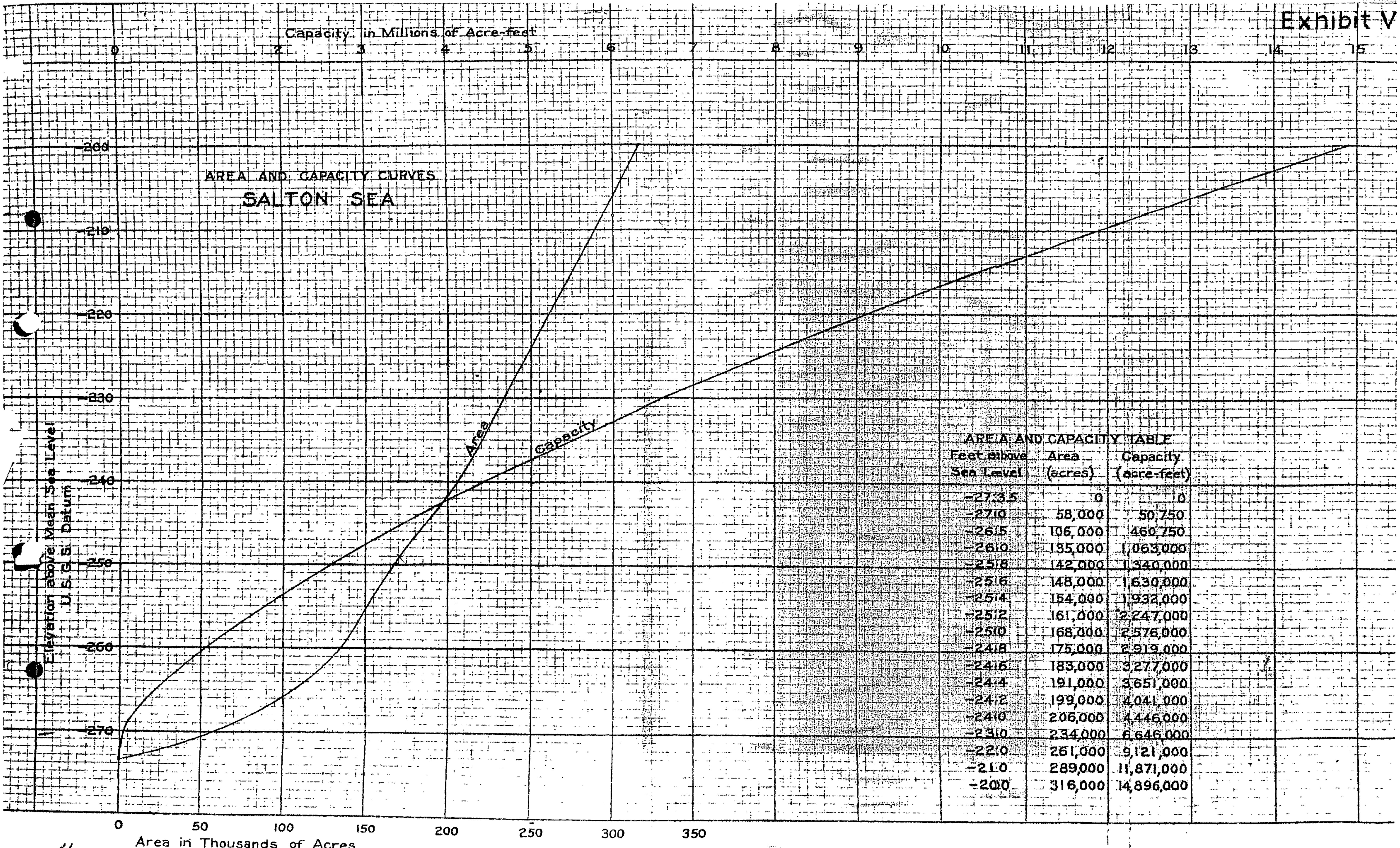
(d) Under present conditions there is being wasted 1.5 acre-feet of water annually per acre irrigated, from the Imperial Valley canal system. Upon the completion of the

All-American Canal, conditions affecting the operation of the canal systems in Imperial Valley will be changed. It is not known to what extent these changes will affect the necessity for wasting water from the system. It is believed that the present value of 1.5 acre-feet per acre irrigated is a liberal estimate of the amount likely to be wasted under future conditions. On this basis, with 925,000 acres irrigated, the amount of water wasted into Salton Sea annually would be 1,387,000 acre-feet.

(e) In order to evaporate the amount of water that may be wasted into Salton Sea under conditions of ultimate development, an average water surface area of 239,000 acres will be necessary. This corresponds to elevation --228 feet.

(f) With Salton Sea at an average stage of -- 228 feet, and the possibility always present of storm water raising this level to --225 feet, it is not likely that any lands below the -- 220 foot contour will have any value for agricultural purposes.

Exhibit V



AREA AND CAPACITY TABLE

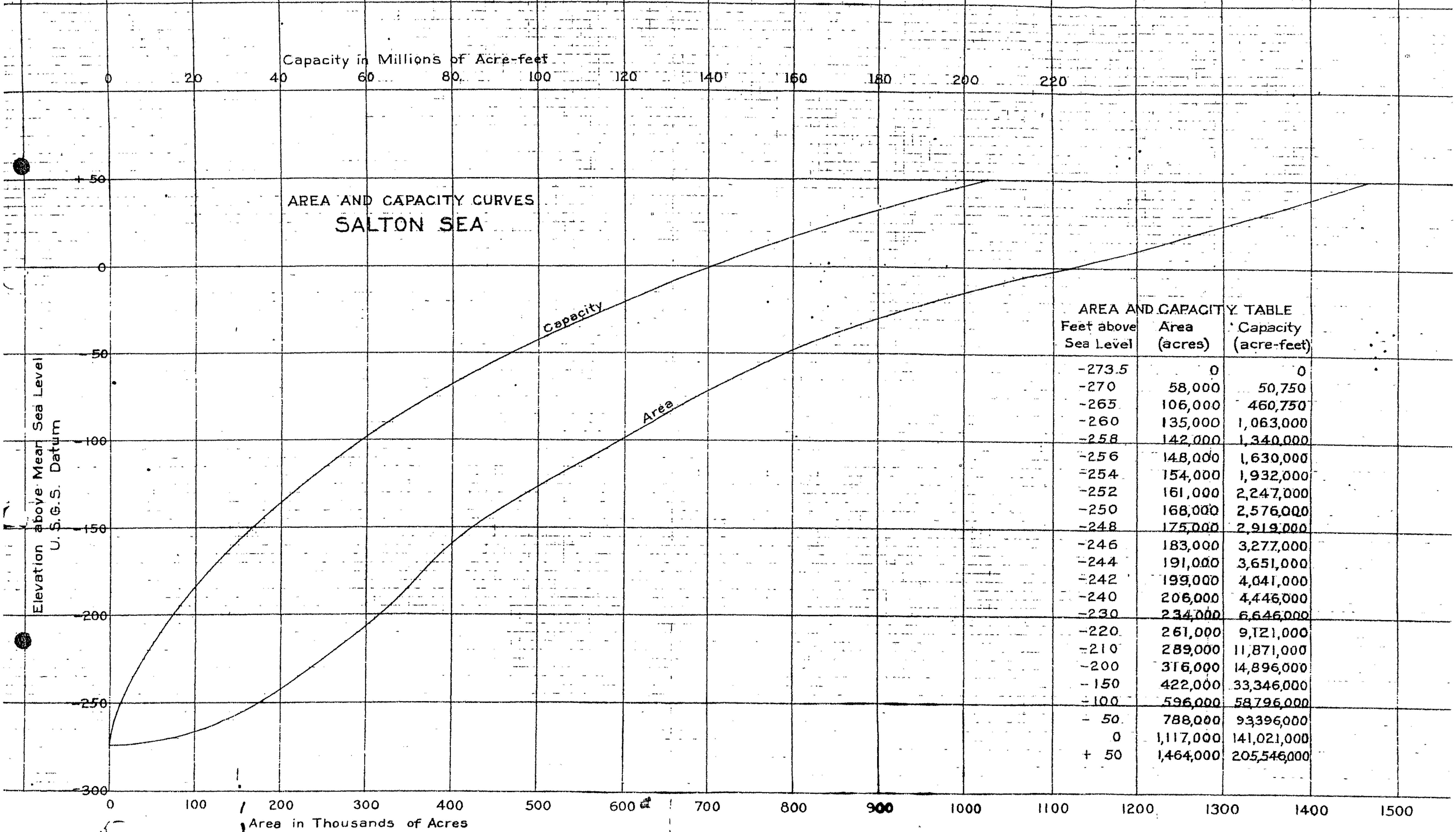
Feet above Sea Level	Area (acres)	Capacity (acre-feet)
-273.5	0	0
-271.0	58,000	50,750
-261.5	106,000	460,750
-261.0	135,000	1,063,000
-251.8	142,000	1,340,000
-251.6	148,000	1,630,000
-251.4	154,000	1,932,000
-251.2	161,000	2,247,000
-251.0	168,000	2,576,000
-241.8	175,000	2,919,000
-241.6	183,000	3,277,000
-241.4	191,000	3,651,000
-241.2	199,000	4,041,000
-241.0	206,000	4,446,000
-231.0	234,000	6,646,000
-221.0	261,000	9,121,000
-211.0	289,000	11,871,000
-201.0	316,000	14,896,000

4

STANDARD CROSS SECTION 10 X 10
KEUFFEL & ESSER Co NEW YORK

MADE IN USA

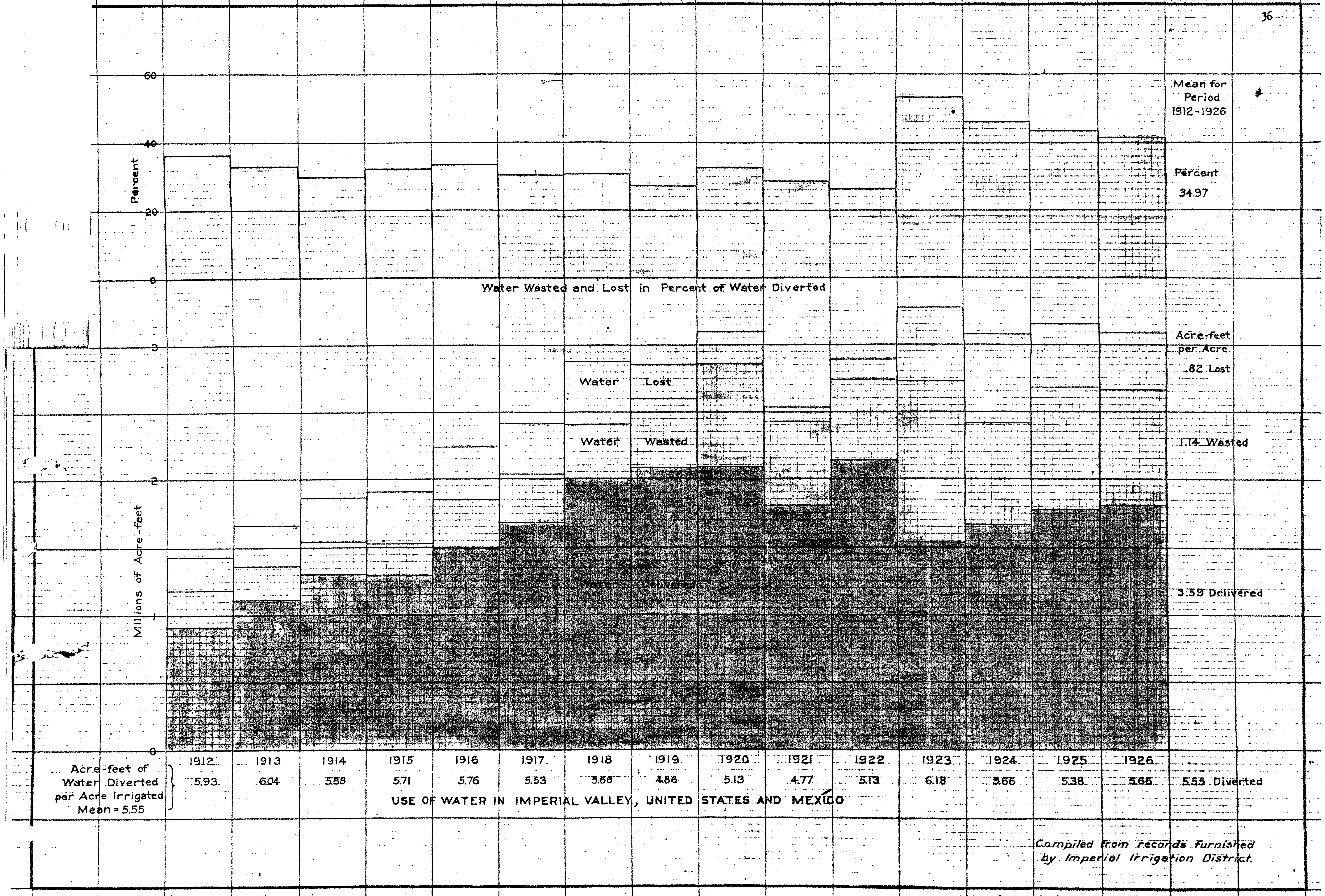
Exhibit V

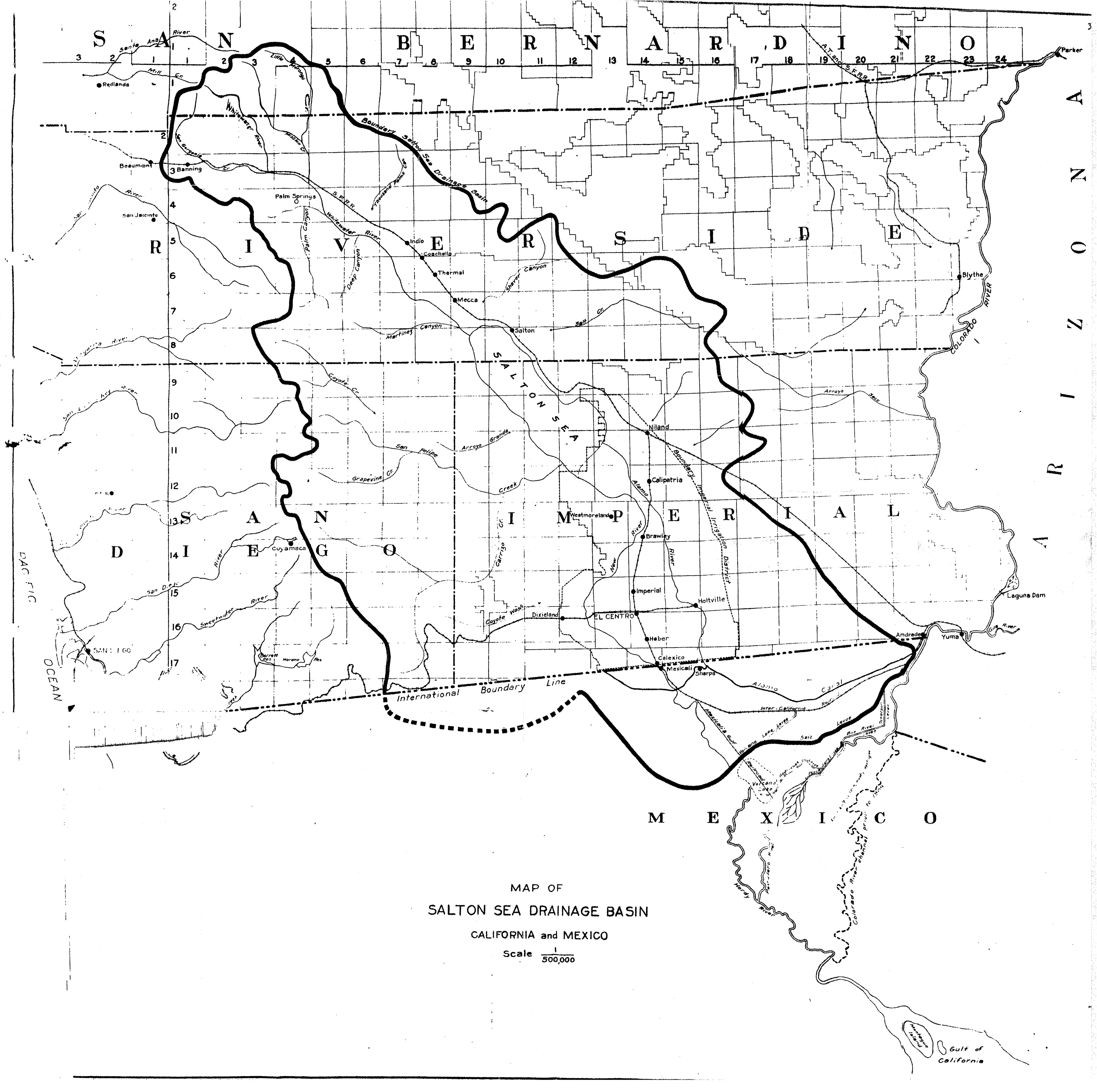


AREA AND CAPACITY TABLE

Feet above Sea Level	Area (acres)	Capacity (acre-feet)
-273.5	0	0
-270	58,000	50,750
-265	106,000	460,750
-260	135,000	1,063,000
-258	142,000	1,340,000
-256	148,000	1,630,000
-254	154,000	1,932,000
-252	161,000	2,247,000
-250	168,000	2,576,000
-248	175,000	2,919,000
-246	183,000	3,277,000
-244	191,000	3,651,000
-242	199,000	4,041,000
-240	206,000	4,446,000
-230	234,000	6,646,000
-220	261,000	9,121,000
-210	289,000	11,871,000
-200	316,000	14,896,000
-150	422,000	33,346,000
-100	596,000	58,796,000
-50	788,000	93,396,000
0	1,117,000	141,021,000
+50	1,464,000	205,546,000

Exhibit IV


Percent
60
40
20
0
Water Wasted and Lost in Percent of Water Diverted
Mean for Period 1912-1926
Percent 34.97
Millions of Acre-feet
3
2
1
0
Water Lost
Water Wasted
Water Delivered
Acre-feet per Acre.
.82 Lost
1.14 Wasted
3.59 Delivered
Acre-feet of Water Diverted per Acre Irrigated Mean = 5.55
1912 1913 1914 1915 1916 1917 1918 1919 1920 1921 1922 1923 1924 1925 1926
5.93 6.04 5.88 5.71 5.76 5.53 5.66 4.86 5.13 4.77 5.13 6.18 5.66 5.38 5.66
5.55 Diverted
USE OF WATER IN IMPERIAL VALLEY, UNITED STATES AND MEXICO
Compiled from records furnished by Imperial Irrigation District.



MAP OF
SALTON SEA DRAINAGE BASIN
CALIFORNIA and MEXICO
Scale $\frac{1}{500,000}$